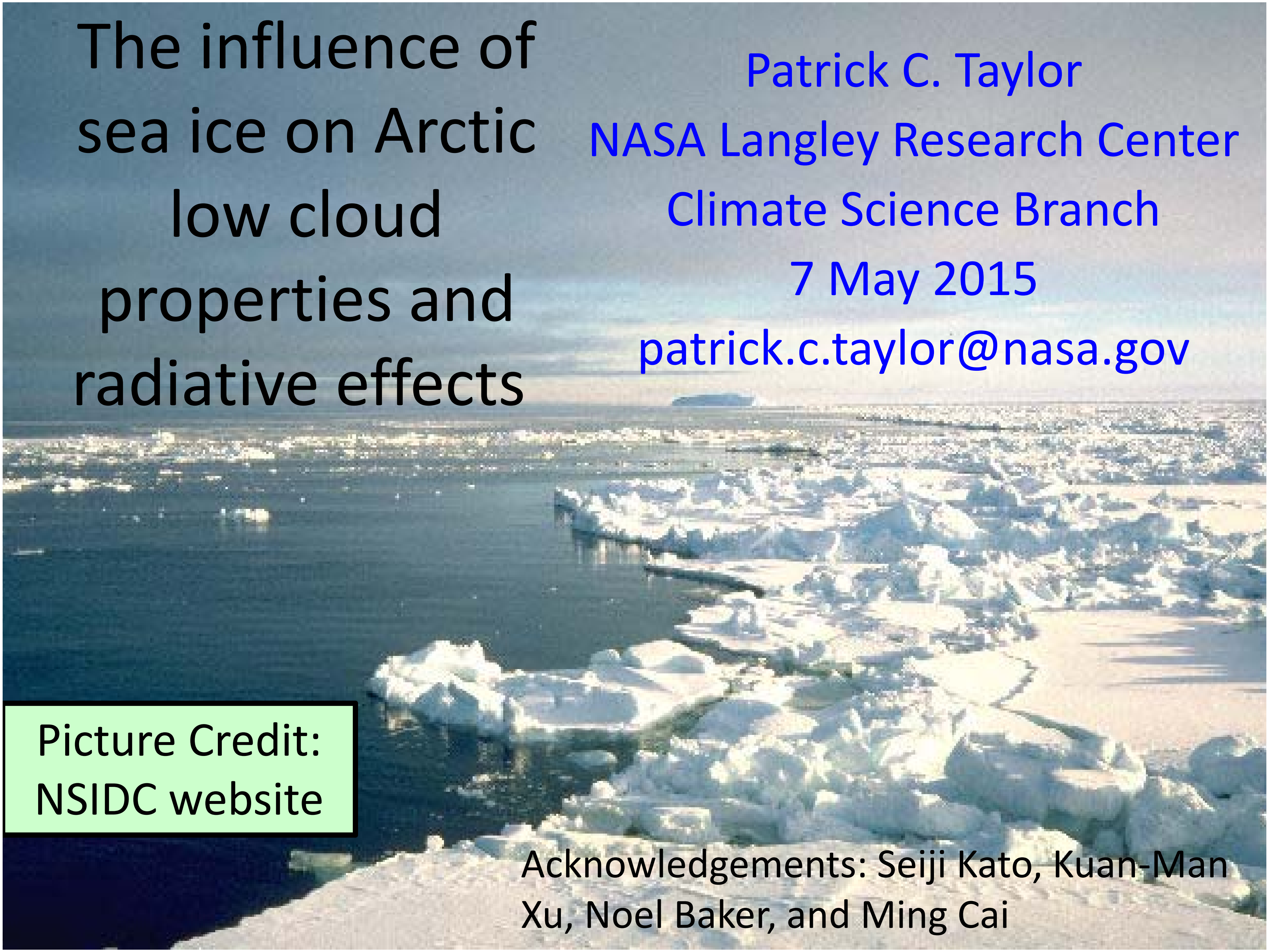

The influence of sea ice on Arctic low cloud properties and radiative effects

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Picture Credit: NSIDC website

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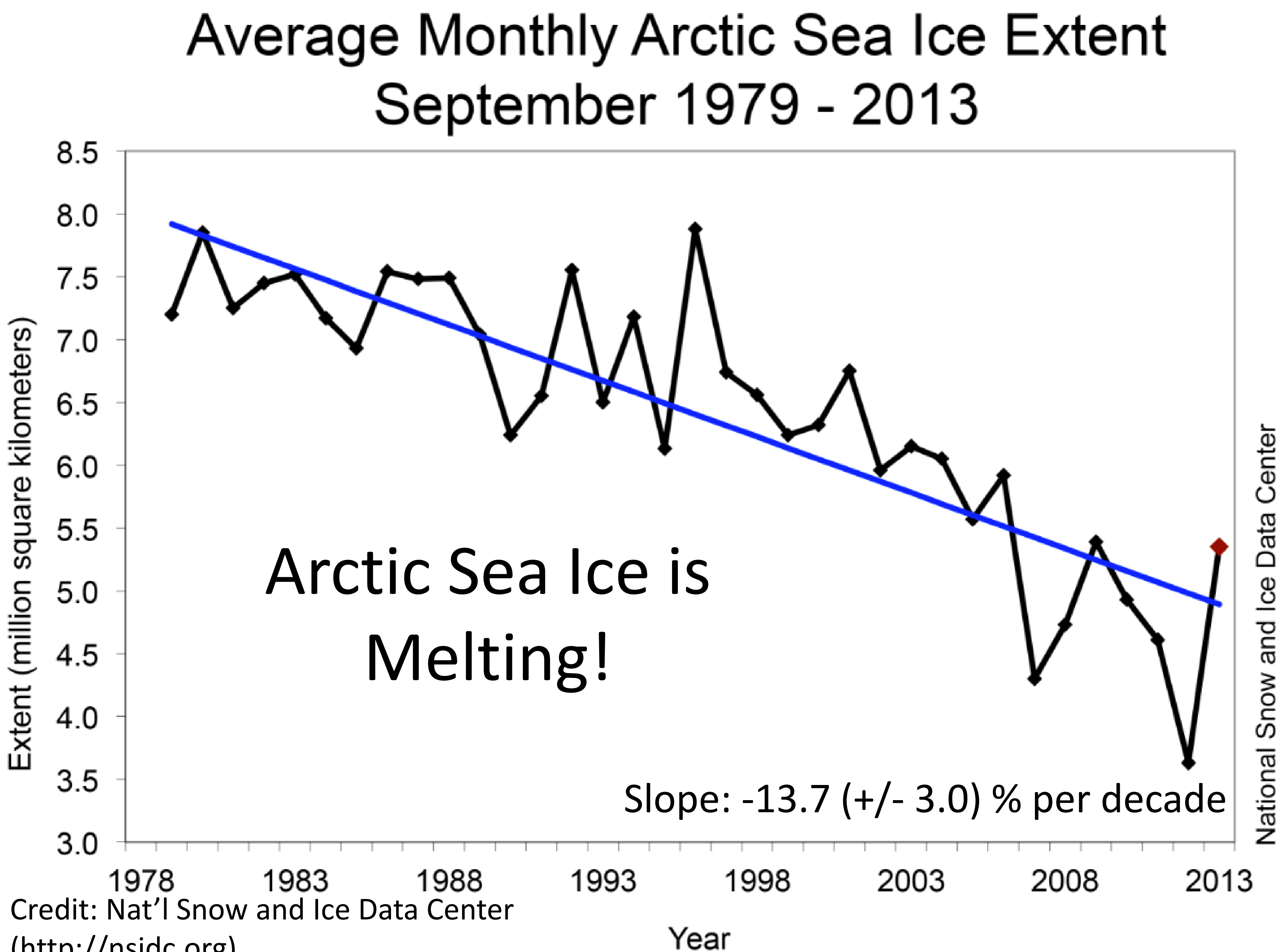
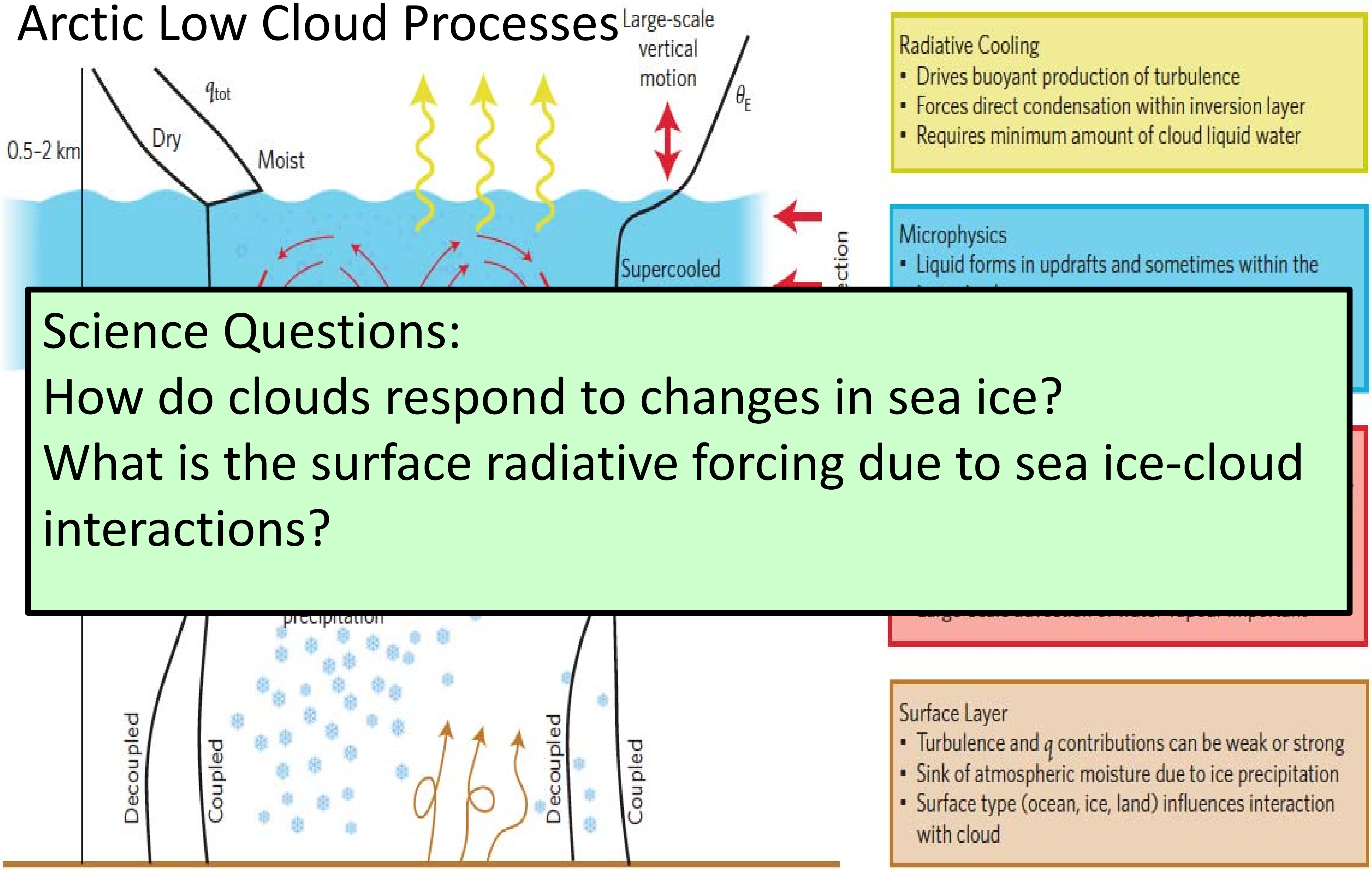


Credit: Nat'l Snow and Ice Data Center (http://nsidc.org)

Arctic Low Cloud Processes



Science Questions:

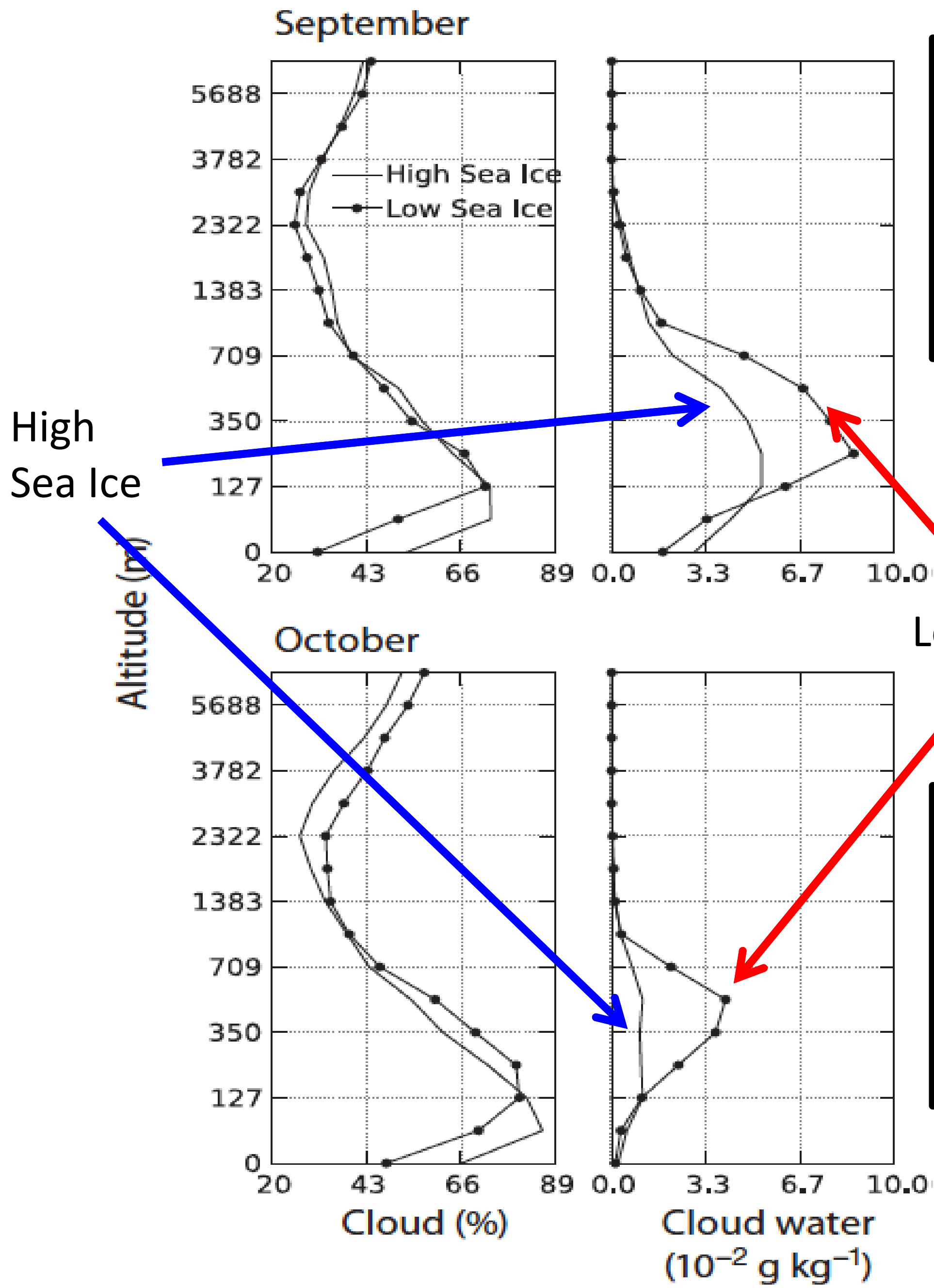
How do clouds respond to changes in sea ice?

What is the surface radiative forcing due to sea ice-cloud interactions?

The influence of the surface type on the cloud properties implies an interaction between clouds and sea ice that may significantly influence Arctic climate change.

Morrison et al. (2012; Nature Geoscience)

Sea ice-Cloud Interaction: Some Modeling Evidence



Cloud base and LWC are higher in Cloud Resolving Model simulations with anomalously low sea ice.

Barton and Veron (2012)

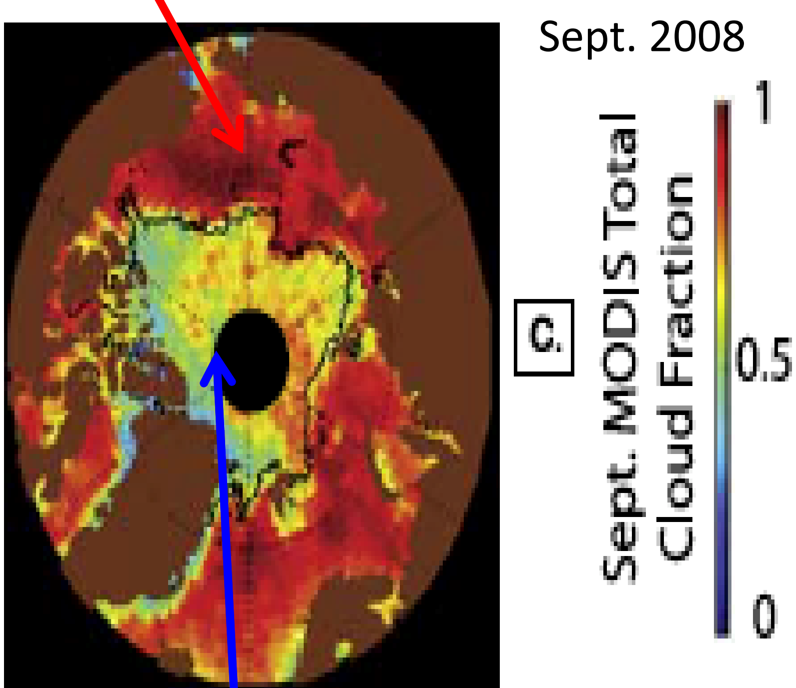
Surface radiative forcing due to sea ice-cloud interactions is only important during Oct. because SW and LW CRF offset in Sept.

Sea ice-Cloud Interaction: Some Observational Evidence

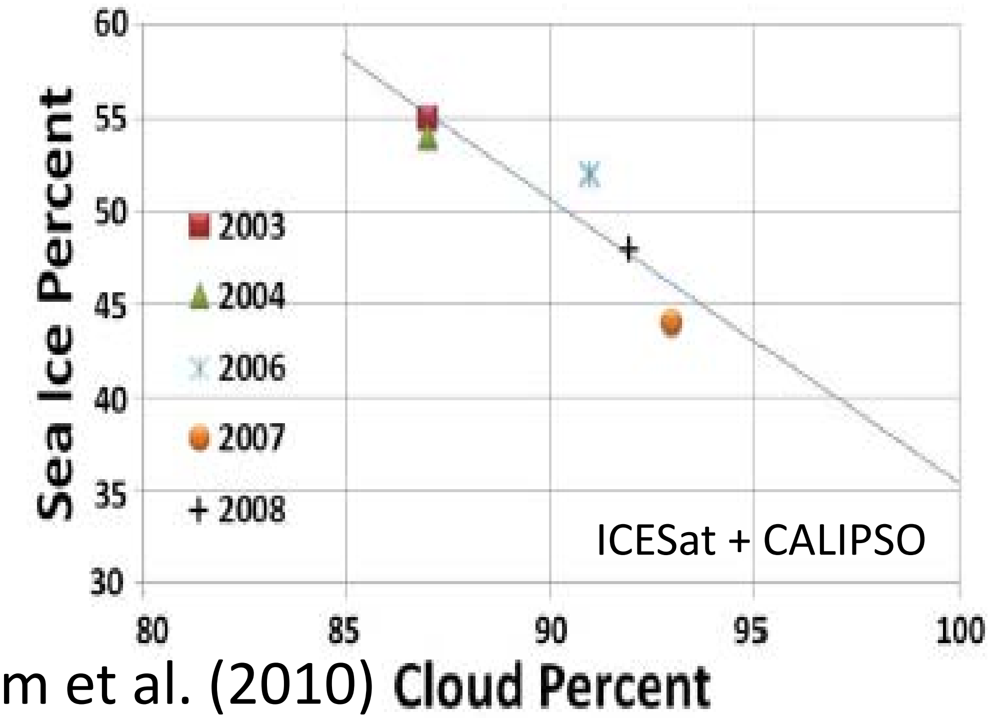
Significant correlation between cloud fraction and the sea ice extent in AUTUMN: larger cloud fraction over open water and lower cloud fraction over ice.

Larger cloud fraction over ocean

Kay and Gettelman (2009)



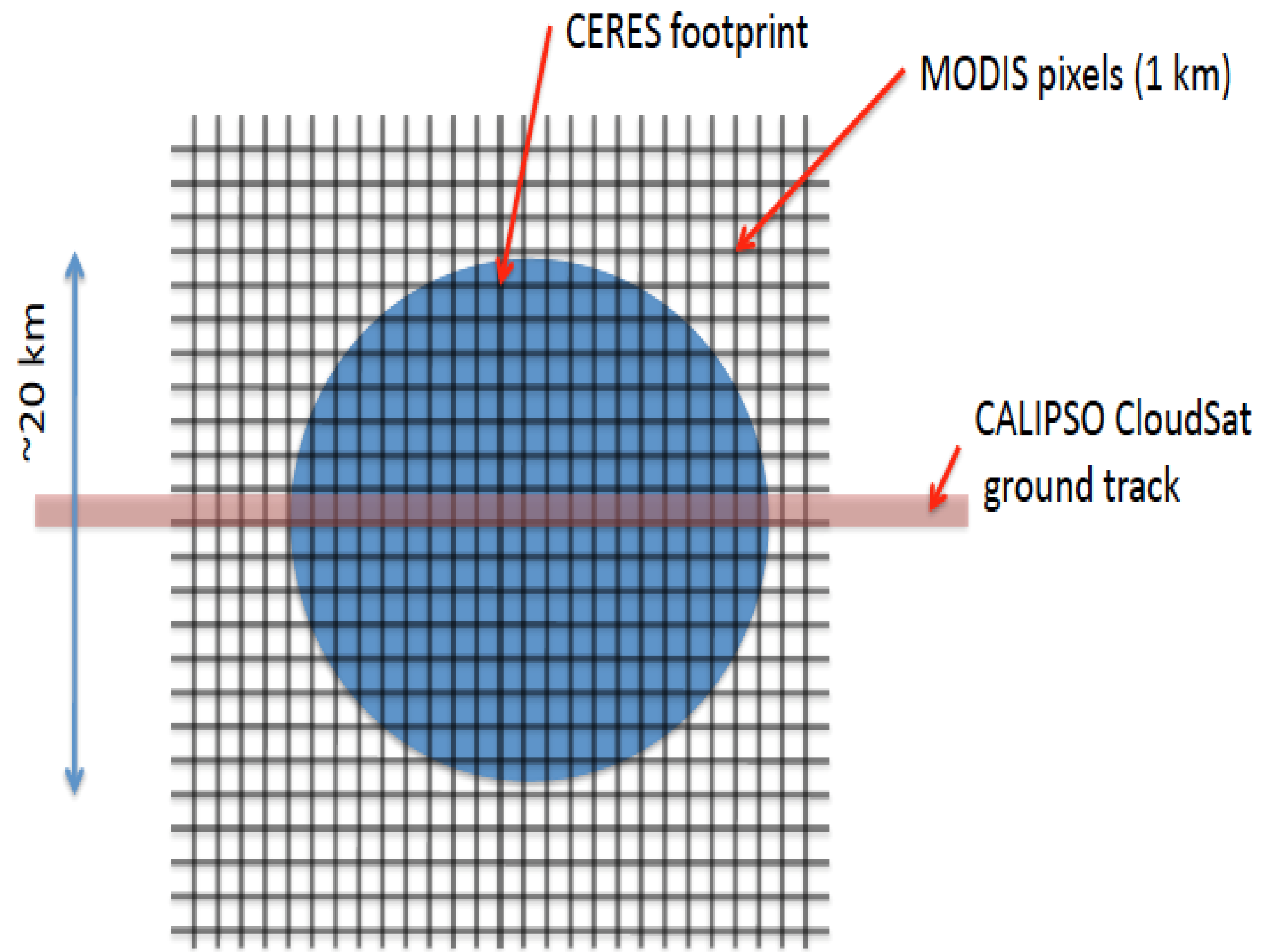
Lower cloud fraction over sea ice



Palm et al. (2010)

No relationship during summer because the atmosphere and surface tend to be decoupled.

CALIPSO-CloudSAT-CERES MODIS (C3M) Merged Data Product (Kato et al. 2010)

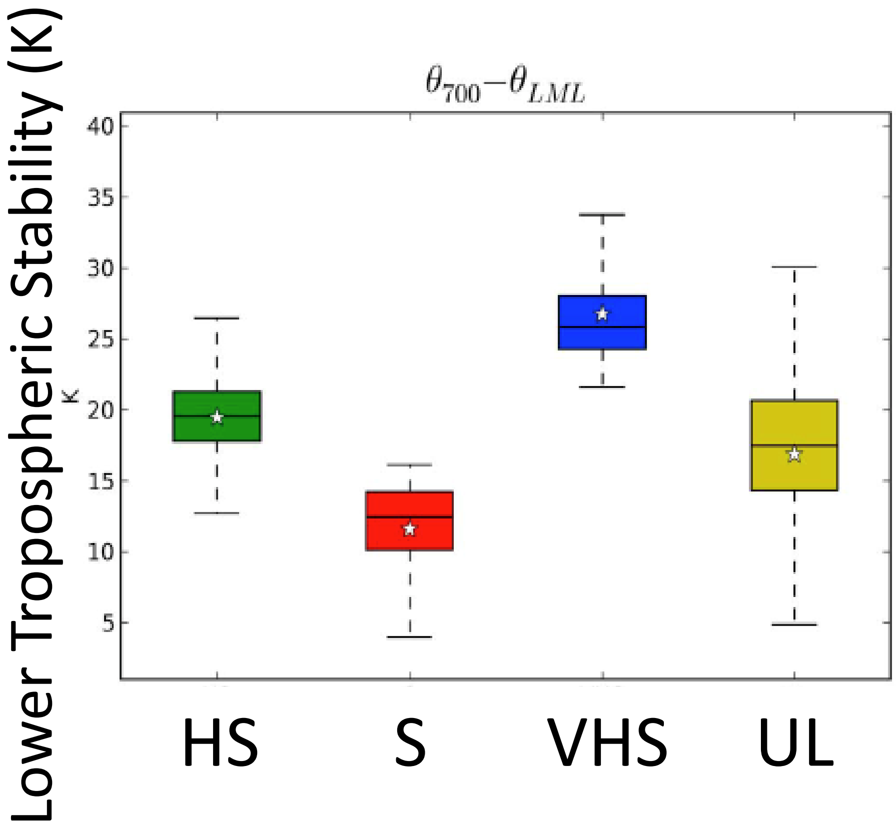


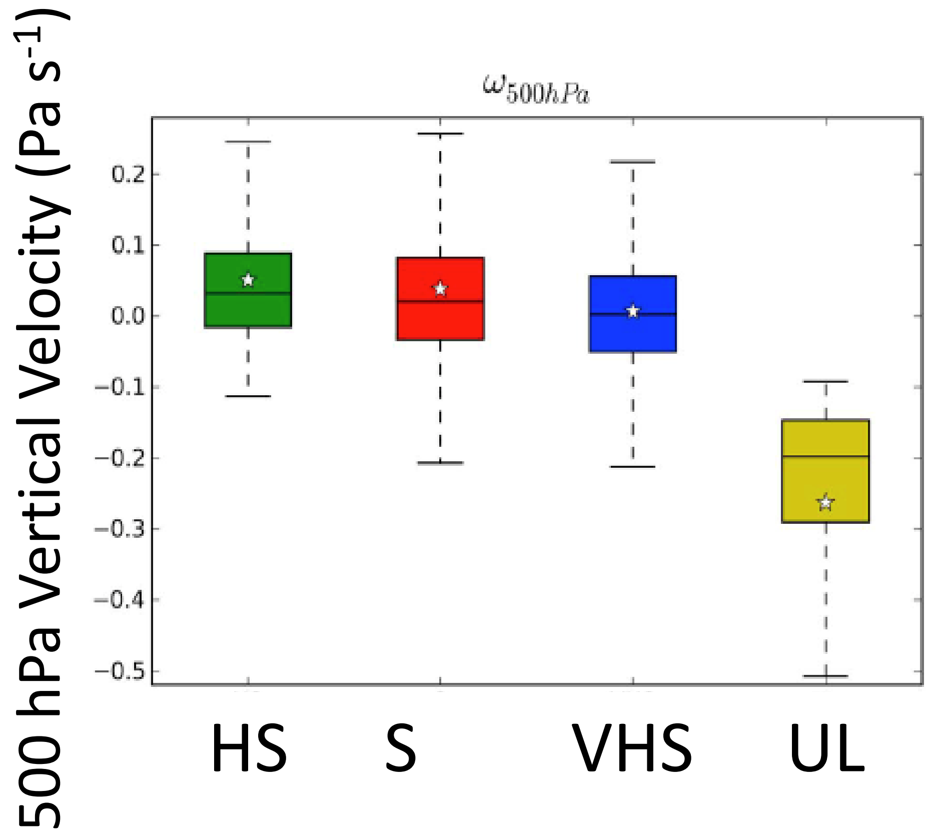
Data contains footprint averaged

1. **Merged CALIPSO-CloudSAT vertical cloud property profiles (cloud fraction, LWC, IWC)**
2. **Computed vertical radiative flux profiles computed with CALIPSO and CloudSat derived cloud properties**
3. **Sea ice concentration (SSM/I)**

Data are available from the NASA Langley ASDC: http://eosweb.larc.nasa.gov/

Atmospheric State Regimes (Barton et al. 2012)





Atmospheric state regimes determined using K-means cluster analysis.

High Stability (HS): 16 K < LTS < 24 K

Stable (S): LTS < 16 K

Very High Stability (VHS): LTS > 24 K

Uplift (UL): ω_{500} < -0.1 Pa s^{-1}

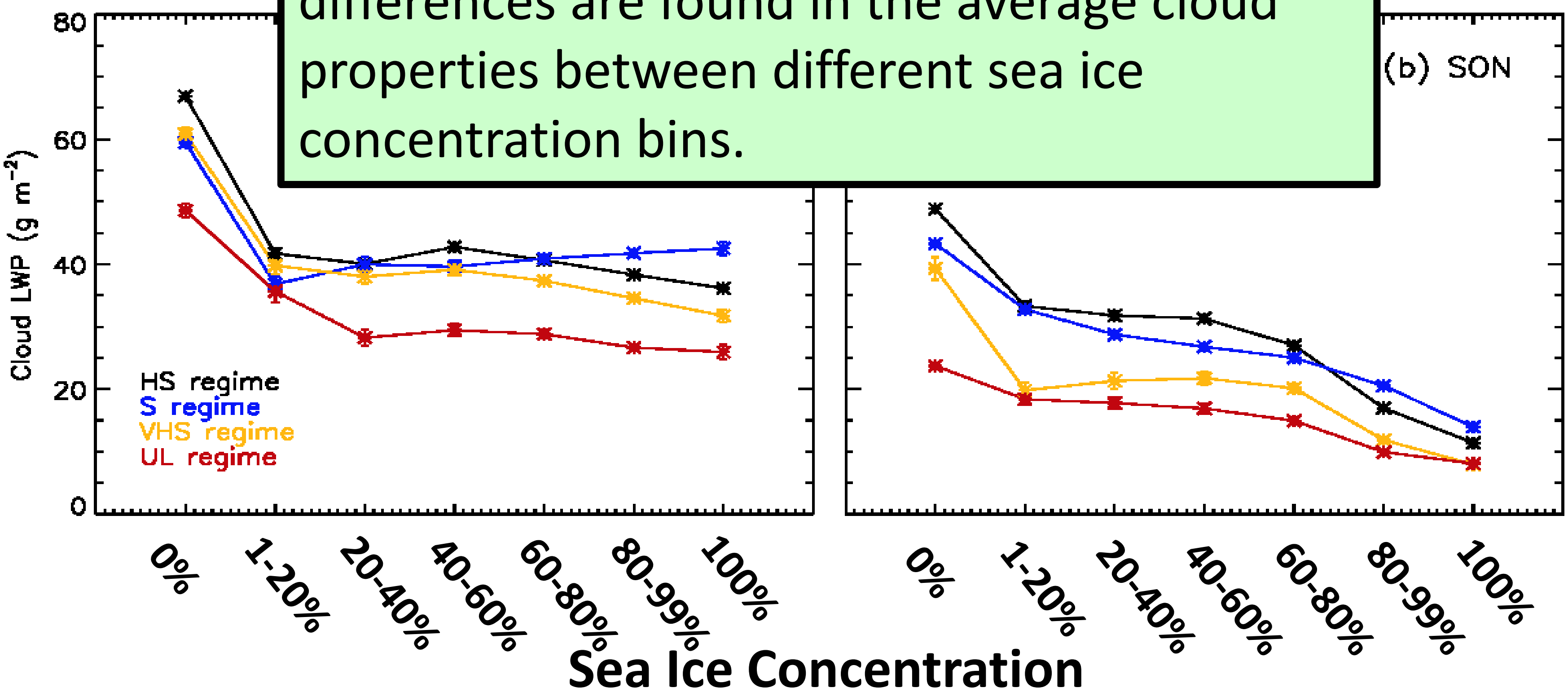
Compositing Method…

(1) Determine the Atmospheric Regime of each satellite footprint using MERRA
(2) Determine the instantaneous sea ice concentration from SSM/I retrieval

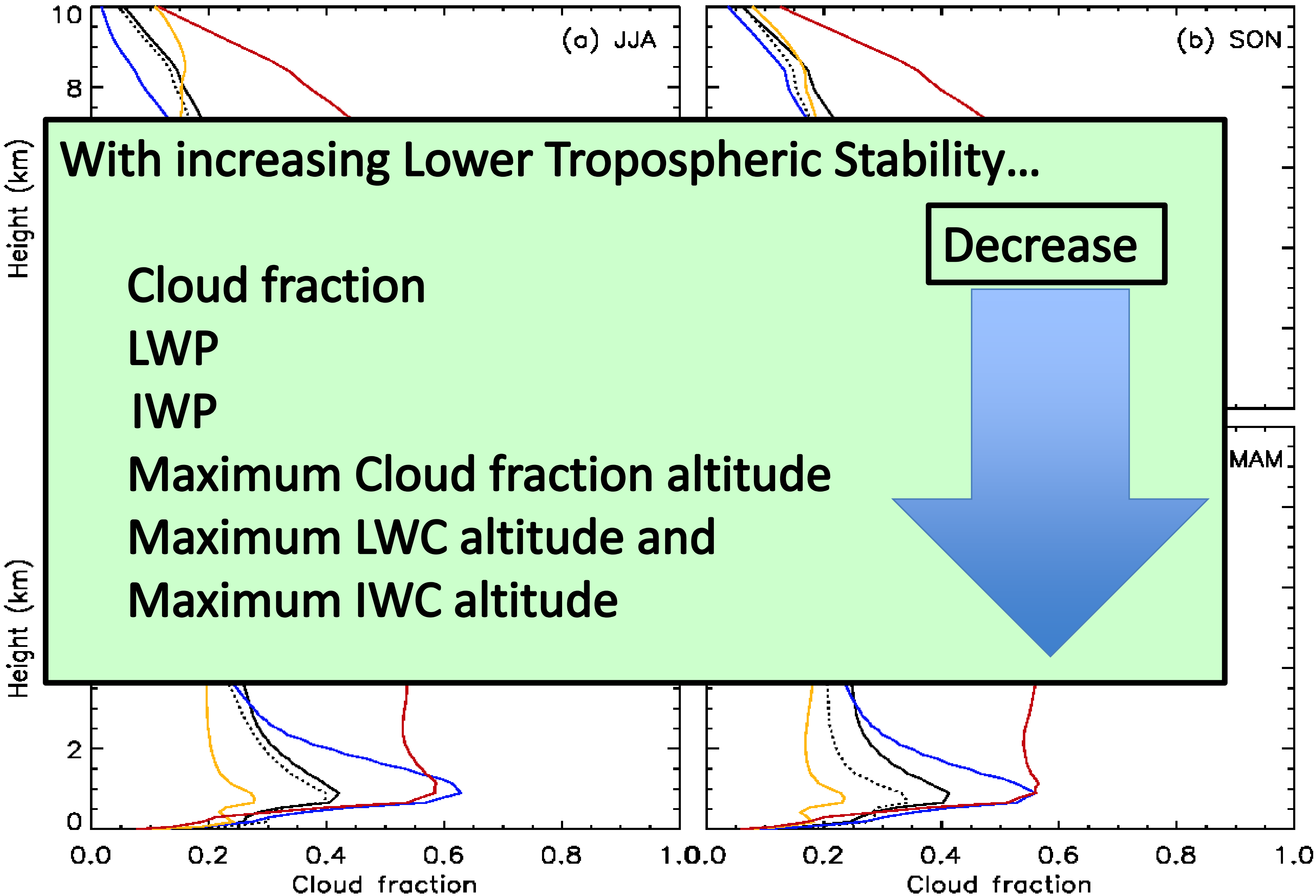
ach

n bin

A covariance between clouds and sea ice is said to occur if statistically significant differences are found in the average cloud properties between different sea ice concentration bins.



Arctic Clouds and Meteorological State



With increasing Lower Tropospheric Stability…

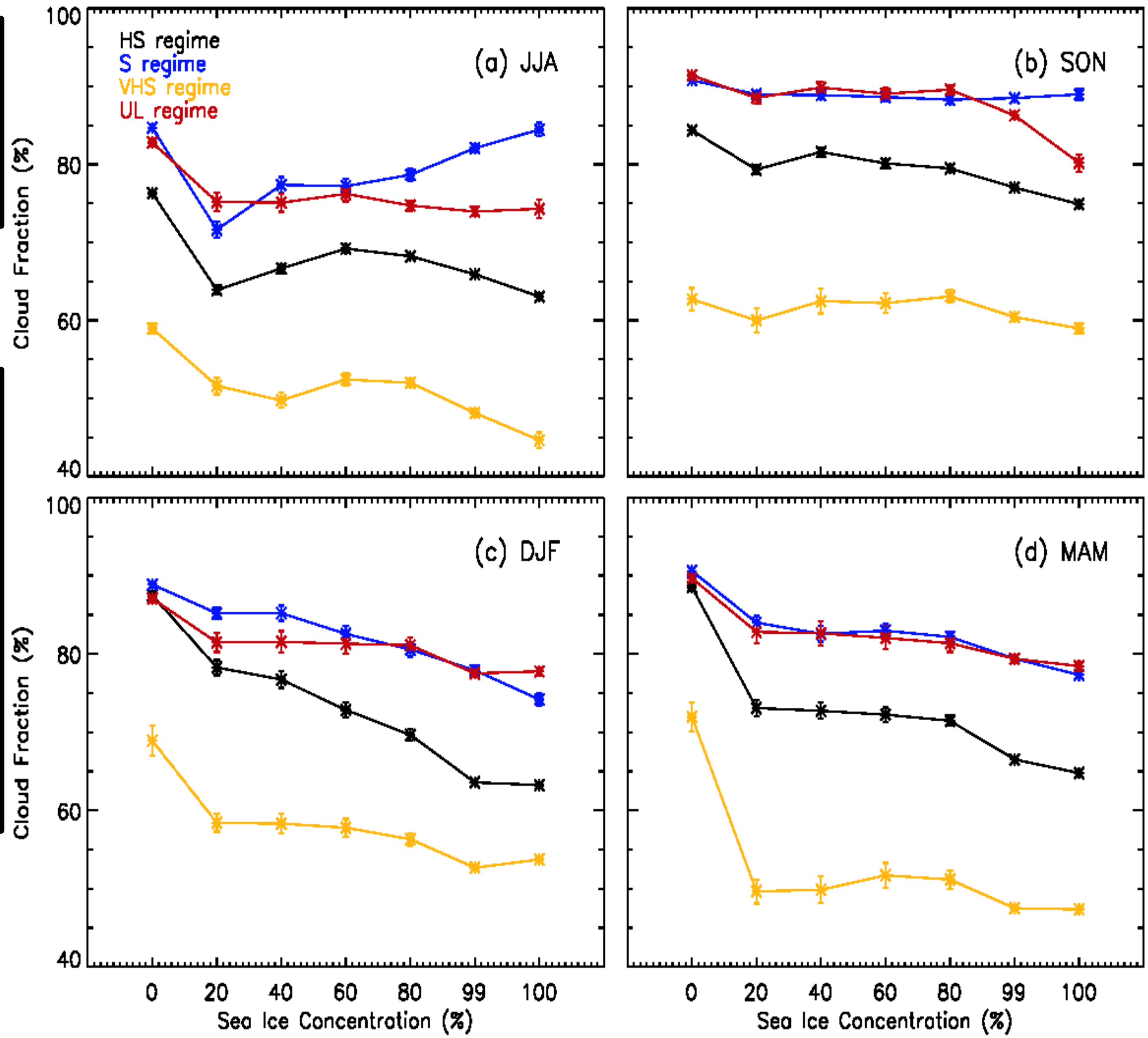
Decrease

- **Cloud fraction**
- **LWP**
- **IWP**
- **Maximum Cloud fraction altitude**
- **Maximum LWC altitude and**
- **Maximum IWC altitude**

Low Cloud fraction vs. Sea ice Concentration

Cloud fraction decreases with increasing sea ice

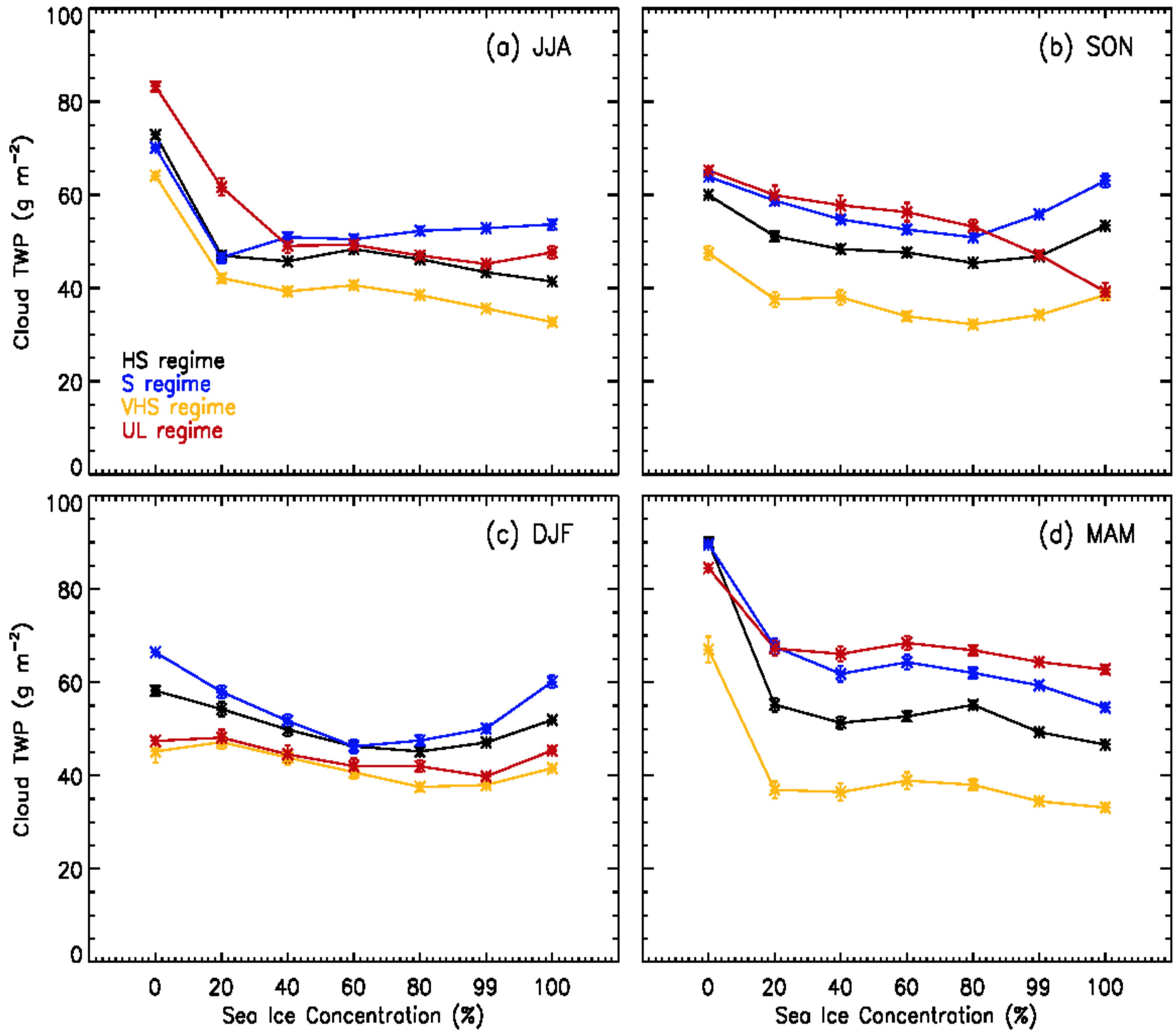
The magnitude of the cloud fraction change with sea ice varies with season and atmospheric regime.

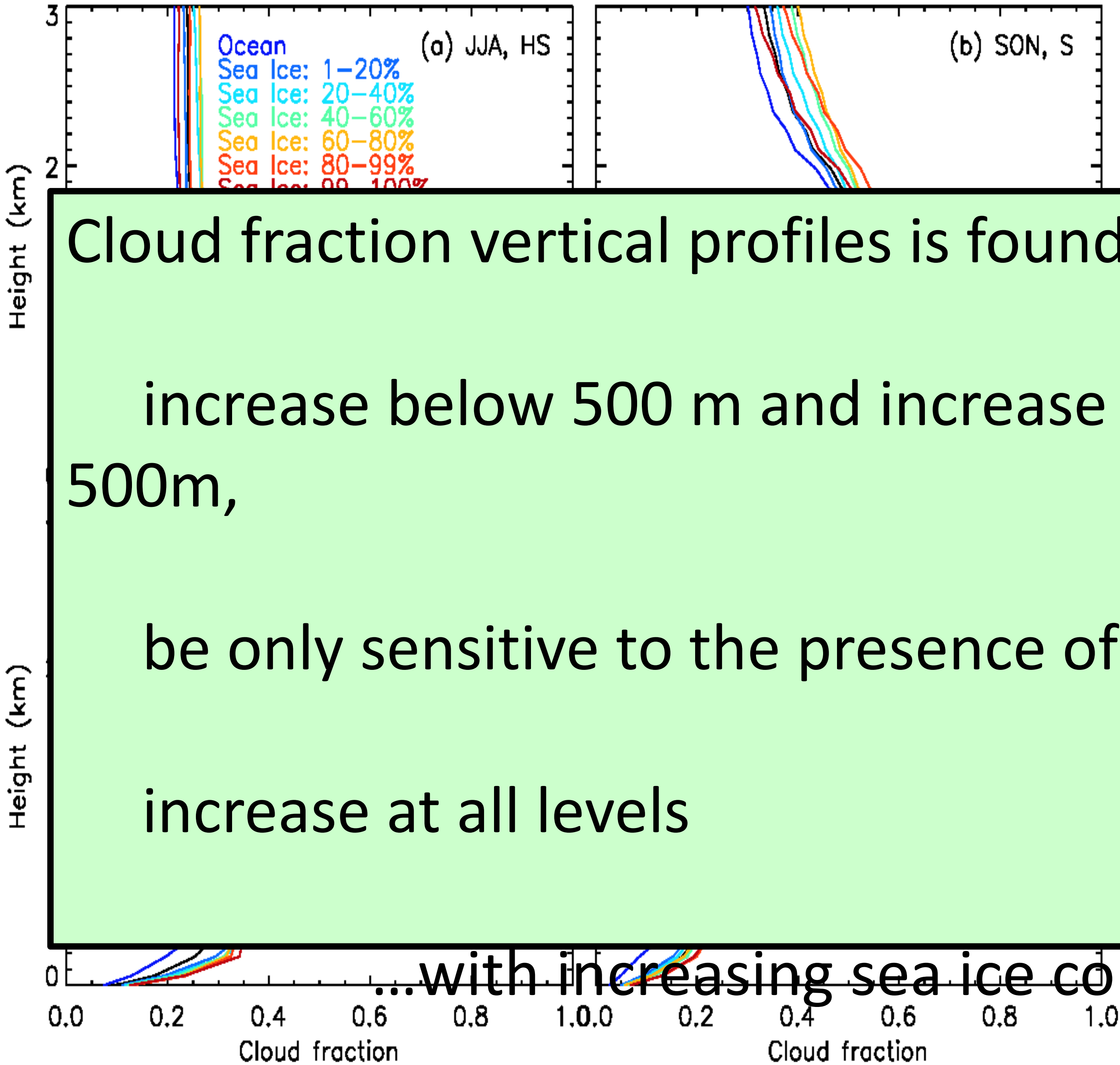


Low Cloud TWP vs. Sea Ice Concentration

Cloud TWP decreases with increasing sea ice

The magnitude of the TWP change with sea ice varies with season and atmospheric regime.





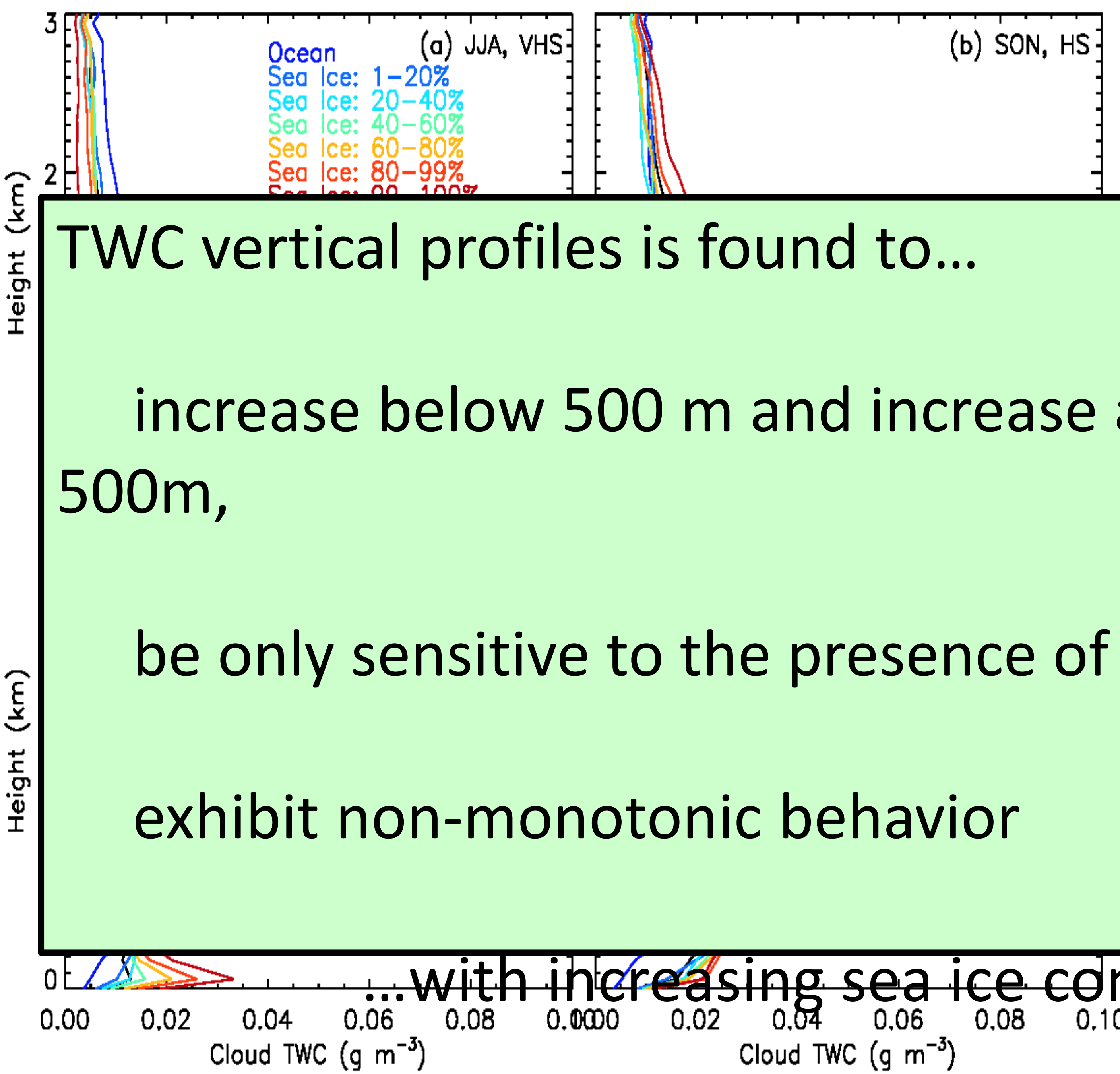
Cloud fraction vertical profiles is found to…

increase below 500 m and increase above 500m,

be only sensitive to the presence of sea ice, and

increase at all levels

…with increasing sea ice concentration.



TWC vertical profiles is found to...

increase below 500 m and increase above 500m,

be only sensitive to the presence of sea ice, and

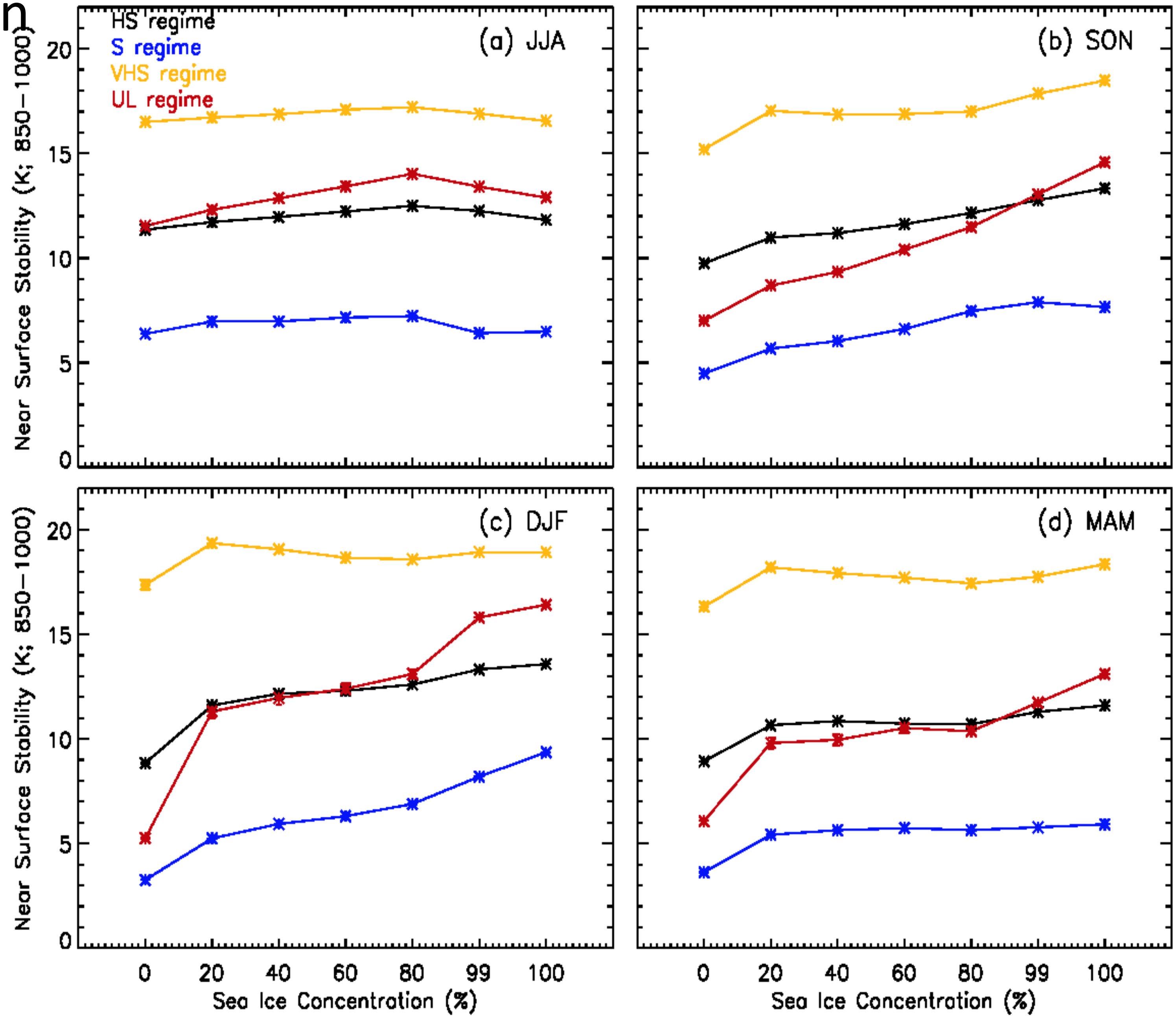
exhibit non-monotonic behavior

...with increasing sea ice concentration.

Boundary Layer Temperature Structure and Sea Ice Concentration

Higher LTS is associated with higher near surface stability.

Near surface stability increase with increased sea ice



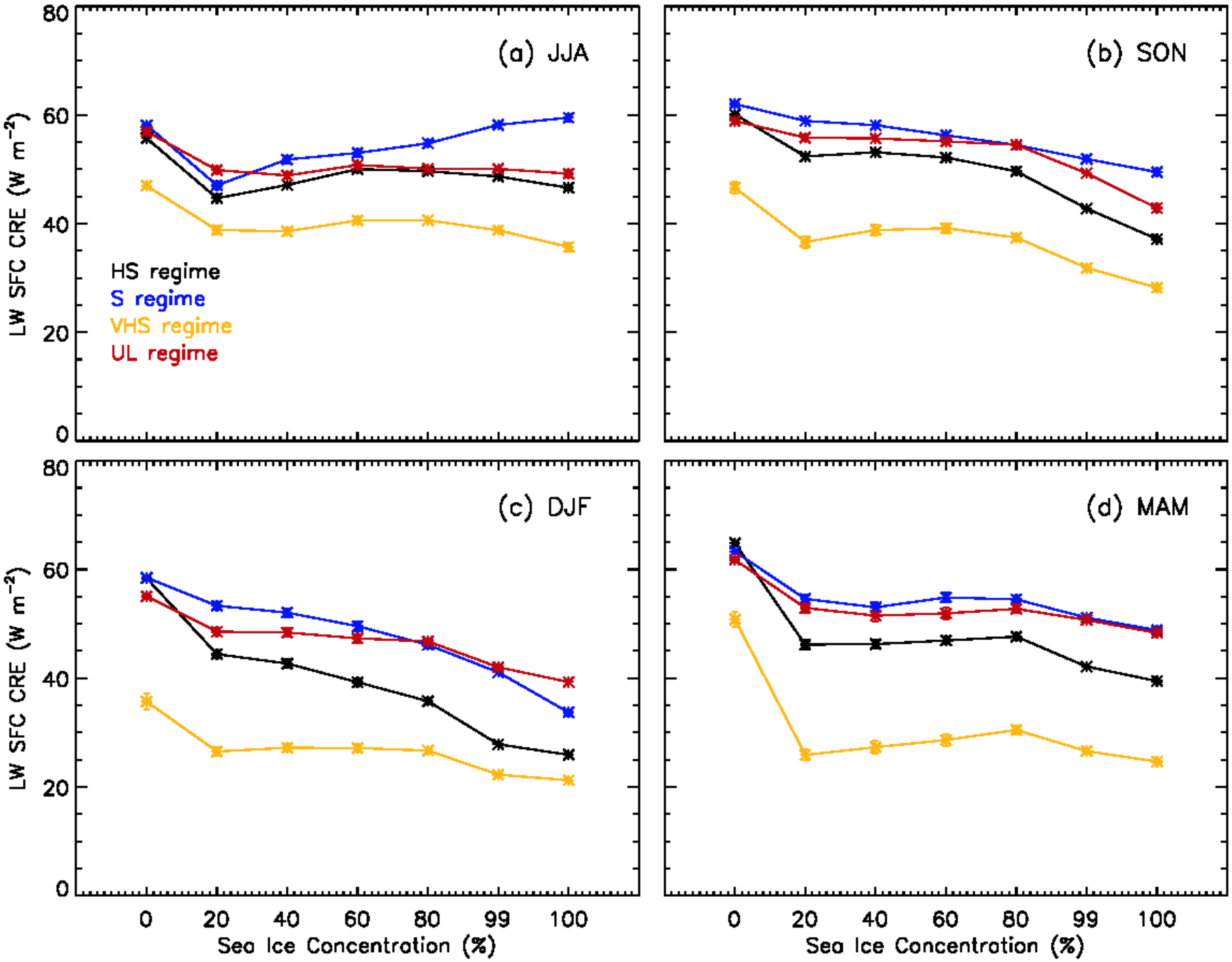
CRE vs. Sea ice Concentration

LW_CRE=LWdn_all – LWdn_clr

SW_CRE=SWdn_all-SWdn_clr*(1-α)

Net_CRE=SW_CRE+LW_CRE

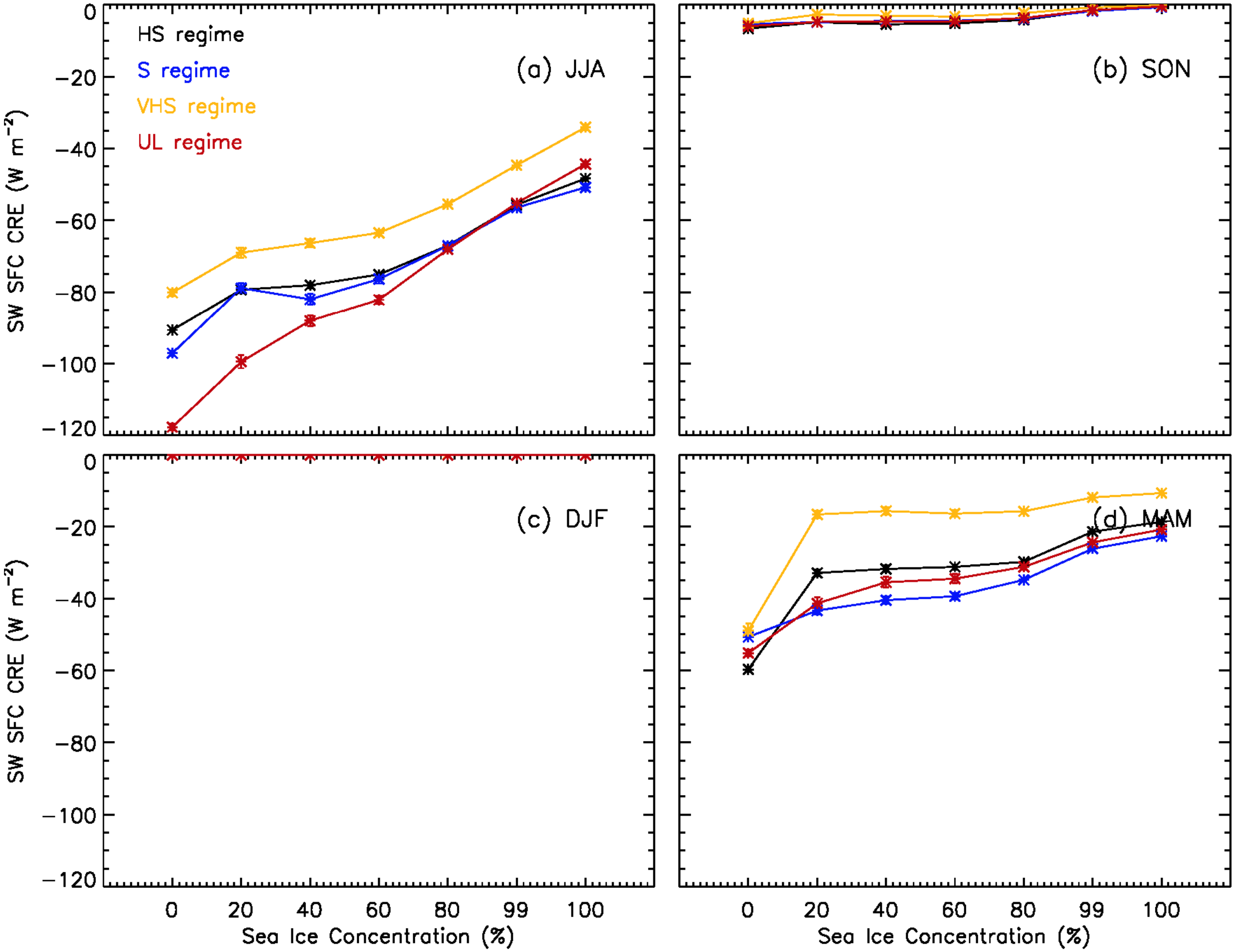
LW Surface Cloud Radiative Effect and Sea Ice Concentration



LW CRE is positive in all seasons.

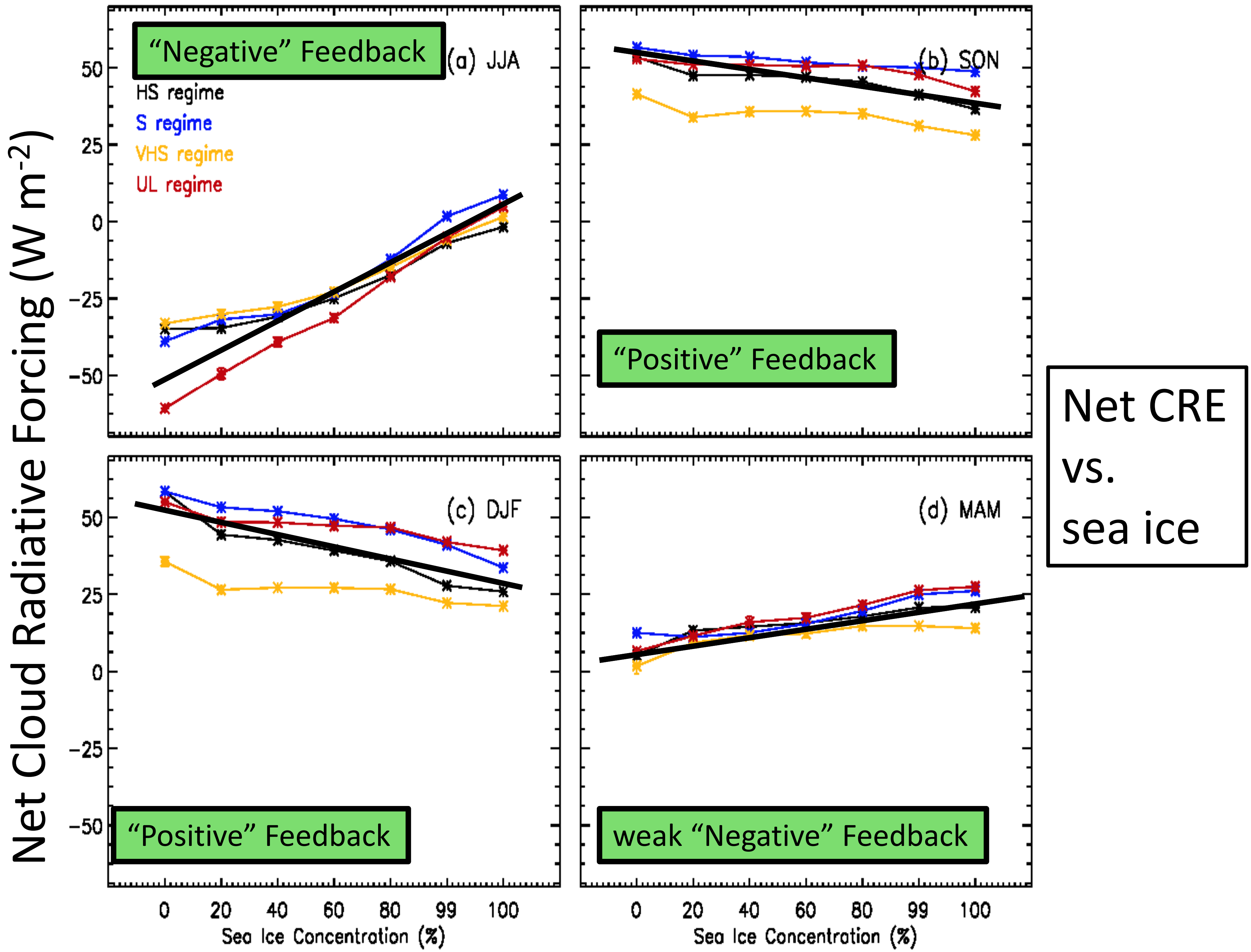
LW CRE tends to decrease with increased sea ice.

SW Surface Cloud Radiative Effect and Sea Ice Concentration



SW CRE is negative in all seasons.

SW CRE tends to decrease with increased sea ice.

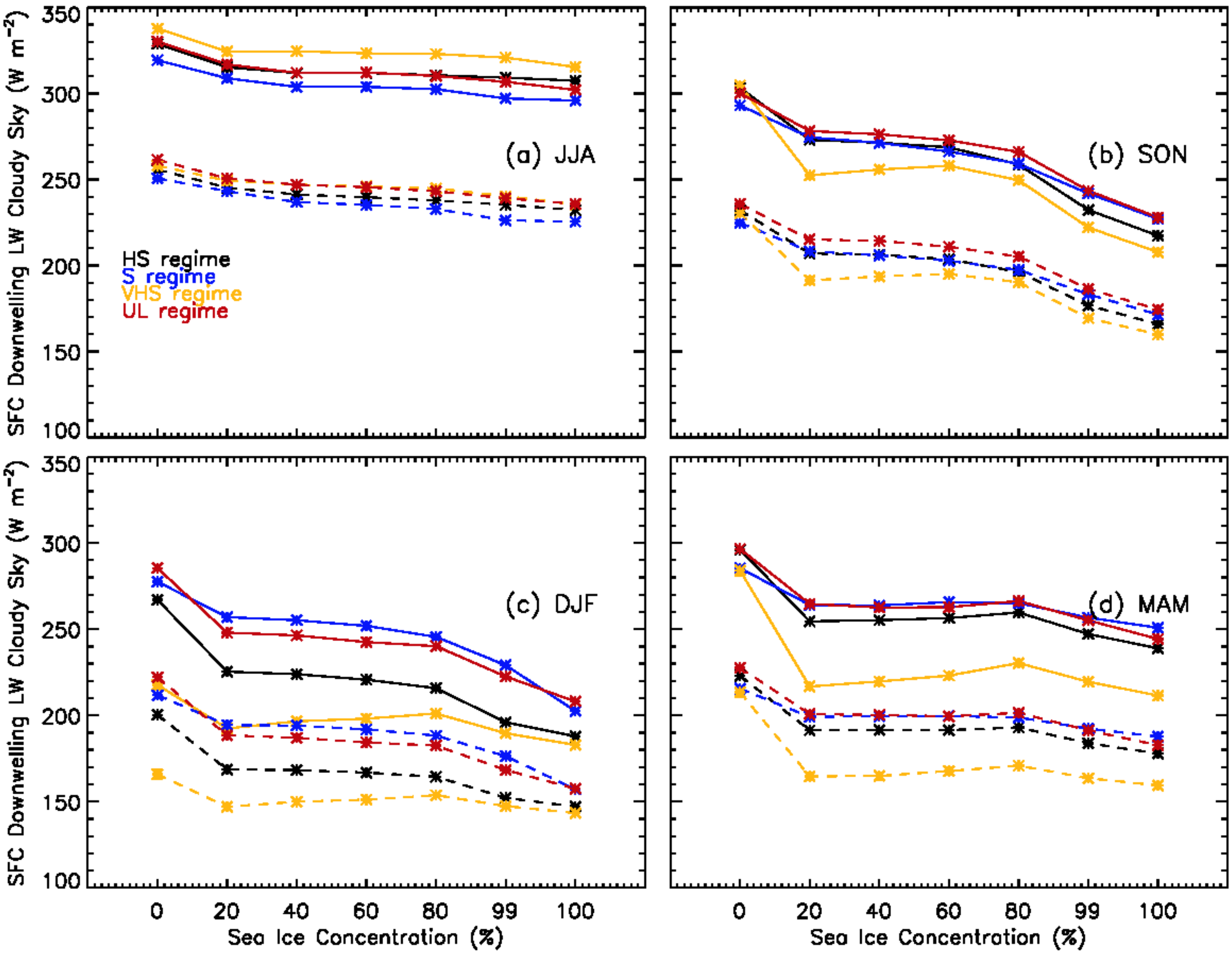


"Negative" Feedback
(a) JJA
HS regime
S regime
VHS regime
UL regime
(b) SON
"Positive" Feedback
(c) DJF
"Positive" Feedback
(d) MAM
weak "Negative" Feedback
Net Cloud Radiative Forcing (W m-2)
Sea Ice Concentration (%)
Sea Ice Concentration (%)
Net CRE
vs.
sea ice

Decomposition using independent column approx.:

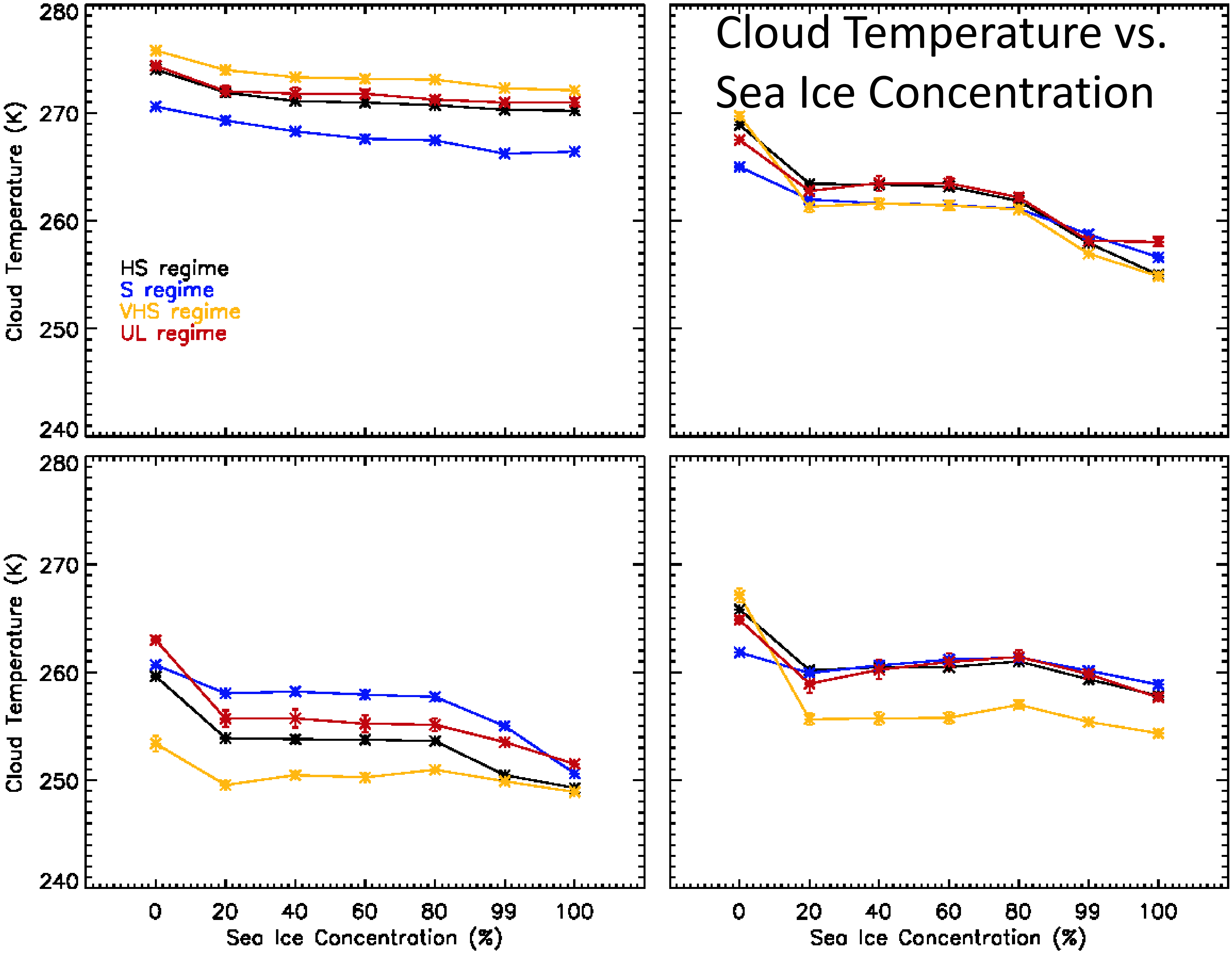
LW_all=(1-N)*F_clr+N*F_cld

Longwave



Both the clear-sky and cloudy sky fluxes decrease with increased sea ice.

Cloud Temperature vs. Sea Ice Concentration



Summary and Conclusion

-Arctic low cloud properties are sensitive to the atmospheric conditions: Cloud fraction, LWP, and IWP decrease with increased stability.

-A statistically significant covariance between Arctic cloud properties and sea ice concentration are found in each regime and season: Cloud fraction, LWP, and TWP decrease with increased sea ice concentration.

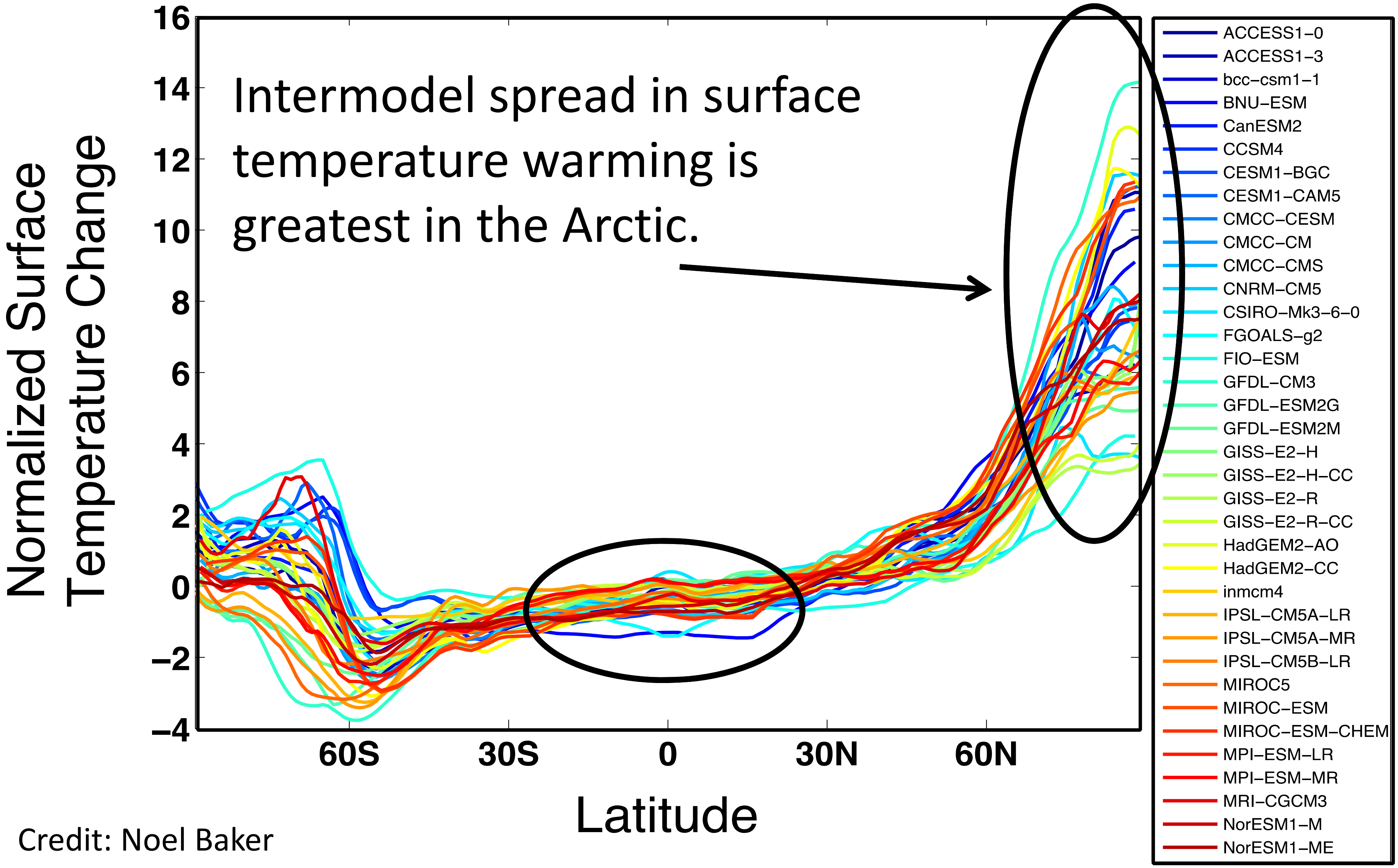
-Covariance between Arctic low cloud properties and sea ice concentration are also found to significantly influence the surface energy budget.

"Negative Feedback" in Summer (SW CRE dominates)

"Positive Feedback" in Fall and Winter (LW CRE dominates)


Questions?

Zonal mean Surface Temperature Response (1% per year CO_2 increase)



Credit: Noel Baker